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CANOPY PENETRATION AND DEPOSITION PATTERNS

FOR INSECTICIDE SPRAY INTENDED FOR WHEAT MIDGE CONTROL

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Saskatchewan Agricultural Research Fund Board)

by

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TABLE OF CONTENTS

		Page
	SUMMARY	(ii)
1	INTRODUCTION	1
2	FIELD TRIAL PROCEDURE	3
3	SAMPLE ANALYSIS AND RESULTS	6
4	DISCUSSION	9
5	CONCLUSIONS	12
6	ACKNOWLEDGEMENTS	13
7	REFERENCES	14
8	TABLES	
	1 Description of Field Trial Location and Type	15
	2 Sprayer operation Details	16
	3 Summary of Meteorological Observations	17
	4 Deposit Data for Natural and Artificial Wheat Head Samples (in μg insecticide/head)	18
	5 Deposition Densities, Recoveries and Droplet Size Spectra for the Four Trials	19
9	FIGURES	
	1 Field Sampling Layout, Trial 1	20
	2 Field Sampling Layout, Trial 2	21
	3 Field Sampling Layout, Trial 3	22
	4 Field Sampling Layout, Trial 4	23

SUMMARY

The physical factors determining the droplet deposition patterns for insecticide spray were investigated through field trial operations carried out on wheat midge infestation and control. Samplers were placed at canopy height and on the ground in these test plots, and were collected and analyzed following the spray application. Nearby wheat heads were collected at the same time and analyzed similarly. Water-sensitive paper was exposed on jumpcards, from which the droplet size spectrum could be determined.

The results indicate that of 45 mg/m^2 of insecticide collected at the top of the wheat crop canopy during an aerial application with conventional cone nozzles, some 25 mg/m^2 reaches the ground and 20 mg/m^2 is collected by the foliage. About 10% of the latter was found on the actual wheat heads, with the remainder presumably impacted on stems and leaves. The foliage-collected fraction tends to increase when a less coarse spray is used. There is some indication that the spray solution penetrates successfully through the outer covering material of the wheat head.

Canopy penetration and deposition patterns for insecticide spray intended for wheat midge control

1. INTRODUCTION

The wheat midge has caused extensive crop damage in the north-eastern part of Saskatchewan for the past three years. As chemical control is expensive, it would appear advantageous to concentrate the control effort on particular stages of the insect's life cycle. Secondly, it would be valuable to have as large a fraction of the spray as possible in droplet sizes that are likely to be deposited where the insects are located at these stages (Yoshida et al, 1984).

The life cycle of the wheat midge follows the pattern of: adult, egg laying and hatching stage, to larvae, cocoon (dormant stage), to pupation and the adult fly again. The latter tend to emerge in July and through to September, having a life span of around three days. The eggs laid during this period hatch within a week. The larvae proceed to a developing kernel of grain where they feed for two or three weeks. Despite their small size (less than 1 mm in length), it appears most promising to direct control measures either against the adult fly or eggs before larval hatch and feeding begins. These considerations in turn indicate that an insecticide spray should produce droplets in sizes that are most likely to become deposited on the wheat stems and heads rather than descending through the canopy to the ground.

Factors affecting the deposition pattern of spray within a crop canopy include: (i) droplet size spectrum, (ii) trajectory orientation as set by the droplets' terminal velocity, wind speeds and turbulence, (iii) surfactant characteristics of the impacted droplets on a wheat head or stem (Maybank et al, 1978). While relatively large droplets

(300-400) are impacted more efficiently on a small object, they will tend to run off after impacting rather than adhering to the wheat head. Furthermore, their larger settling velocities will carry them downward at a steeper angle, thereby reducing the likelihood of interception by the crop target. On the other hand, very small droplets (>50μ) will move through the upper portions of the canopy at angles conducive to capture by one of several wheat heads, and once impacted will tend to adhere; however, their impaction efficiencies are relatively low. It seems on balance that droplets in the intermediate size range of 50-200μ might be most readily impacted and retained on the wheat head where the midge larvae are found.

The primary purpose of this study was to determine what fraction of a typical insecticide spray, applied for wheat midge control, was retained on the crop and what fraction became deposited on the ground. Secondly, information on the droplet size spectrum was sought, with a view to determining whether the canopy deposit fraction was different for different droplet sizes. Thirdly, an attempt was made to establish whether insecticide initially deposited on the surface glume penetrated through to the seed.

A series of three trials carried out by Agriculture Canada in the Tisdale area to investigate the efficacy of a particular insecticide for wheat midge control afforded an opportunity to study at the same time these physical characteristics of the spray. Two were aircraft applications, and the third a groundrig test. A fourth trial on a different aircraft was carried out at Canora.

2. FIELD TRIAL PROCEDURE

The first two trials at Tisdale were designed to compare the efficacy of Lorsban 4E (chlorpyrifos) at the low and high volume spray rates, when applied by a Piper Pawnee aircraft using conventional hollow cone nozzles. The third trial was intended to compare the penetration characteristics when a high volume rate was applied by a slower moving, groundrig device, specifically the Spracoupe, model 220. In the fourth trial, at Canora, the spray was produced by an Agwagon aircraft fitted with rotary atomizers. The times and locations for each trial are given in Table 1, the plot designations for the first three being set by Agriculture Canada.

In trial one, the aircraft spray was applied from 25 conventional hollow cone nozzles (type D10-45) operated at a hydraulic pressure of 175 kPa and designed to apply 18 L/Ha of solution at the Piper Pawnee"s cruising speed of 175 km/h. For the higher volume spray trial (#2) 45 of the same nozzles were operated along the boom, at the same hydraulic pressure, to provide a nominal application rate of 35 L/ha. For trial #3, the Spracoupe applied solution at a rate of 70 L/ha from 40 flat fan nozzles (#80065) oriented vertically and spaced at 25 cm. For trial #4 the Agwagon aircraft was equipped with four Micronaire R rotary atomizers, set to apply insecticide solution at a rate of 13.5 L/ha. These details are set out in Table 2.

For the first three trials, insecticide was applied to the test plots at the same rate, viz. 45 mg/m^2 of active ingredient (.45 kg/ha, roughly equivalent to a half pound per acre). Hence, the solutions used contained 2.5, 1.3 and 0.64% active ingredient respectively. To these solutions a known amount of BSF fluorescent dye was added as a tracer,

and for analysis purposes. In trial #4, the spray solution was water only, without any insecticide.

The wheat field used for trials 1-3 had been divided for the efficacy study into 15 plots, each 200 m x 35 m; two swath applications covered one plot in each case. The plots designated A4, A2 and C3 were used for trials 1, 2 and 3, respectively. For trial 4 a strip of wheat field 100 m long by 15 m wide was sprayed once. The field layouts for the four trials are shown in Figures 1-4, with the sampler locations identified by numbers in each.

In trials #1 and 2, two petri dishes (15 cm in diameter) were placed out at each of the 12 sampling sites, one on the ground and one mounted horizontally at approximately the crop canopy top (75 cm). In addition, a jumpcard of water sensitive indicator-coated paper was placed beside the ground level dish, from which a measure of the droplet size spectrum could be obtained (Maybank et al, 1976; Yoshida & Wallace, 1980). Four artificial models of wheat heads, constructed from polyethylene rope mounted on fine wires were placed at canopy height at each site; they, plus four natural heads collected after the spray operation were viewed under UV light and then analyzed for dye content. The artificial heads were used to determine if dye extraction losses from the natural heads was a problem in the analysis, something that had been observed in previous research (Yoshida et al, 1984). Further sets of natural heads were collected from each site roughly 16-20 hours after the spray operation; analysis of these provided information on the behaviour of the dyed droplets subsequent to deposition.

For trial #3, only jumpcards were used, a pair being exposed at each of the four sites 29, 30, 31, and 32 (see Fig. 3), one on the

ground and the other placed horizontally at 75 cm (canopy top). In addition four natural wheat heads were collected from each of these sites after the spraying.

In trial #4, jumpcards were exposed at the five sites identified in Fig. 4, with some of the canopy top ones being shaped into cylinders 6 cm long by 1 cm diameter, rather than being used as flat collecting surfaces. In this way they present a target to the drifting spray that is roughly comparable to that of a wheat head, and so they served as artificial wheat head collectors.

Meteorological observations were taken at the time of each trial. For trials 1 and 2, a complete observing station was used, from which continuous records of air temperature, dew point, wind direction, temperature gradient and wind speeds at 0.5, 1, 2 and 4 metres could be abstracted. For trials 3 and 4 only hand-held instruments were available. Table 3 gives a summary of the weather conditions for each trial.

3. SAMPLING ANALYSIS AND RESULTS

Following each trial, the sample dishes, jumpcards, and wheat heads (natural and artificial) were collected. The latter were viewed under UV light for the presence of dyed droplets of the spray. Subsequently, dye extraction from both the wheat heads and the petri dishes was effected using known amounts of industrial-grade ethanol (Yates, 1963; Maybank et al, 1976). Analysis was by fluorescence spectrophotometer, calibrated from BSF dye standards prepared at the time. The initial values were corrected for loss through photolysis of the dye, and converted to equivalent amounts of chorpyrifos insecticide (the active insecticide ingredient) on the basis of the relative concentrations of dye to chemical in the spray solution for that trial. For trial #4 this was done, solely for comparison purposes, assuming an active ingredient had been present at a level sufficient to apply 45 mg/m^2 to the sprayed area.

The resulting values for each wheat head sample were averaged; the results, together with standard deviations, are given in Table 4. For some of the natural wheat heads, the outer materials (glume) were carefully stripped away and analyzed separately from the seed component. Averages for these data with standard deviations, are also given in Table 4. Finally, the natural heads collected the following day (16 to 20 hours after spraying) were analyzed for dye content, converted to mass of active ingredient and averaged (see Table 4).

The mass of dye in each petri dish converted and corrected to equivalent mass of insecticide was divided by dish area to give deposition densities in mg/m^2. These were in turn averaged for each 12 dish sample set (i.e. at the ground and at canopy top) for each of the two

trials in which they were used. The results are given in Table 5. While petri dishes were not exposed in trials 3 and 4, it is possible to obtain rough estimates of deposition densities from the droplet size spectrum of the jumpcards, by converting the number of droplets per unit area in each size range to a mass per unit area of insecticide and then summing these quantities. The resulting values are less reliable than the chemical analysis, and so are given in Table 5 in parentheses. The ratio of the deposition density at canopy height to the nominal application rate is a measure of recovery, and is given as a percentage in Table 5.

The difference between the ground level deposit density and that at canopy height is a measure of the deposit per m^2 of field area that was collected by the crop canopy: wheat heads, stems and leaves. These amounts are given in row 5 of Table 5, while in row 6 these values are presented as a percentage of the total incoming deposit (i.e. the canopy top density).

For row 7 of Table 5, the deposits in μg of chemical per head found for natural wheat heads (top row of Table 4) have been converted to mg per m^2 of field area, based on an estimate of 200 heads per m^2 (i.e. sufficient for 1 g of grain per head to provide a yield of 2000 kg/ha). These must be considered very rough estimates at best. Microscopic sizing of the stains on the jumpcards provided droplet size spectra for each trial. Dew deposition after spraying prevented this determination for trial 1 (most, but not all the jumpcards in trial 2 were similarly affected). The resulting volume median diameters (the size below which 50% of the spray volume is found) are given in

Table 5, together with a measure of the spread of droplet sizes (the geometric standard deviation, σ_g, which increases with increasing heterogeneity of the spray).

4. DISCUSSION

The most salient fact to recognize in both Tables 4 and 5 is the wide range of values for individual samples: the standard deviations are frequently as large as the means, especially for the wheat heads. This is to be expected, given the high degree of variability observed for pesticide spraying, at least on the scale of small area samples. Conclusions have to be drawn carefully with this in mind.

Visual inspection of the natural wheat heads after spraying indicated the presence of only a few droplets, typically two to eight on each head. For trials 1 and 2, where the droplet MD was 360μ, three such droplets would contain 1-2 μg of insecticide. The generally larger deposits per head tabulated in the first row of Table 4 would suggest that the more numerous smaller drops were likely missed in the visual observation. The averages for wheat head deposit in Table 4 clearly increase as the droplet size diminishes (trials 2, 3 and 4); there is also an increase observed between high and low volume spray (trials 1 and 2), even though the rate of application of the active ingredient remained the same. Why this should be is not clear (the difference is significant at the 5% level by Student's t-test). It may be due to an unintended difference in droplet size spectrum, as the latter could not be obtained in trial 1, or to a higher actual spray rate than the nominal for trial 2 (see recoveries, Table 5).

There were significantly higher deposits, on average, on the artificial wheat head replicas (by a factor of 3 to 4). This may be due to enhanced collection geometry, better retention after impaction, or improved dye extraction efficiency. Only the last factor would make their use in subsequent trials relevant.

Again from Table 4, it is apparent that penetration through the glume material is occurring, with roughly 50% of the total wheat head deposit (or at least of the dye) being found on the stripped head. It is likely that the insecticide has been similarly partitioned.

This is not nearly so certain for the fraction remaining after some 20 hours, where it appears that 75% of the dye is recoverable in both trials. The reduction may well be due to photolytic or hydrolytic decomposition of it and not of the insecticide. On the other hand, if the decrease is caused through wash-off by overnight dew formation, loss of both dye and insecticide could be proportionate.

The deposit densities at canopy top, given in Table 5, are reasonably correlated with the nominal application rates for trials 1 and 2 (the latter is a bit high, though at 130% recovery it is not outside the range that the large standard deviation would impose). By undercounting the numerous small droplet fraction, it is known that estimates of deposit density based on the jumpcard drop size spectrum tend to be low. Hence, density figures for trials 3 and 4, while internally comparable, cannot be directly related to the petri dish or wheat head values.

Comparison of ground level and canopy top deposit densities indicate that some 40-70% of the spray is deposited on the foliage and the fraction gets significantly higher as the droplet spectrum VMD decreases from 360 to 145μ. For trials 1 and 2 this fraction translates into some 20 mg/m^2 of insecticide being deposited on various portions of the wheat plant. That the majority of this crop deposit is not on the wheat head is apparent when the figures of row 5 (Table 5) are compared with those of row 7, based on dye analysis of wheat head deposits (Table 4) and

reasonable estimates of the number of wheat heads per m^2. For trials 1 and 2 only some 10% of the crop deposit is on the head (the equivalent figures for trials 3 and 4 are not really comparable as they are based on different methods of deposit assessment).

Finally, it should be noted that all the sprays were fairly heterogeneous, (i.e. a wide range of droplet sizes were present) as evidenced by $_{o}g$ values of 1.2 to 1.4. The spectrum tended to be somewhat narrower in trial 2, for the D10-45 cone nozzles, than for the other two types. This would be an advantage if a VMD of 360 represented the most desirable droplet size, but would be a disadvantage if that were not the case.

5. CONCLUSIONS

1) From this preliminary investigation, it would appear that a considerable fraction of both aircraft and groundrig applied insecticide is collected by a wheat crop but that only a small portion of this becomes deposited on the actual wheat heads.

2) The fraction of the insecticide spray depositing on wheat heads and other components of the crop foliage tends to increase as the droplet size is changed from 300μ and above, down to sizes in the 100-200μ range.

3) Once the stage in the wheat midge life cycle at which chemical control could be most economical has been established, the location of the population at that stage can be used to identify the most promising droplet size spectrum to employ. More detailed field trials would then be necessary to determine nozzle types, pressures and operating conditions. The alternative merits of aircraft and groundrig, and of conventional nozzles vs rotary atomizers should be further investigated as well.

4) From dye analysis techniques it would appear that spray solution does penetrate the glume and so would come in contact with midge larvae residing inside the wheat head. Direct analysis for the insecticide is, however, indicated to confirm or refute this finding.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Maybank, J., K. Yoshida and S.R. Shewchuk: Comparison of swath deposition and drift characteristics of groundrig and aircraft herbicide spray systems. SRC Publication No. P-76-1, 1976.

Maybank, J., K. Yoshida, S.R. Shewchuk and R. Grover: Spray Drift Behaviour of Aerially-applied Herbicide: Report of the 1977 Field Trials. SRC Report P-78-2, 1978.

Yates, W.E. and N.B. Akesson: Fluorescent tracers for quantitative micro-residue analysis. Trans. Amer. Soc. Agr. Eng. 1962.

Yoshida, K., K. Wallace, W.E. Yates and M.A. Atiemo: Droplet drift and penetration of aerially applied FURADAN into wheat heads in control of orange blossom wheat midge. SRC Tech. Rept. E-910-6-B-84. 1984.

Yoshida, K. and K. Wallace: Determination of dynamic spread factor of water droplets impacting on water-sensitive paper surfaces. Jr. Col. Interface Sci., 63(1): 164-168, 1980.

Table 1. Description of Field Trial Location and Type

Trial No.	Location	Date	Time	Plot No.	Application	Nozzle	Chemical
1	Tisdale	July 14 1985	6:35 p.m.	A4	Piper Pawnee D Type	Hollow Cone	Lorsban 4E
2	Tisdale	July 14 1985	7:15 p.m.	A2	Piper Pawnee D Type	Hollow Cone	Lorsban 4E
3	Tisdale	July 15 1985	12:25 p.m.	C3	Spracoupe High Clearance Model 220	Flat Fan	Lorsban 4E
4	Canora	July 24 1985	4:10 p.m.	Municipal Airport	Agwagon Aircraft	Rotary Atomizer	Water

Table 2. Sprayer Operation Details

Trial No.	Nozzle Type	Number of Nozzle	Hydraulic Pressure (kpa)	Cruising Speed (km/hr)	Cruising Height (m)	Desired Application Rate (L/ha)	Area Sprayed (m^2)	Crop Growth Stage
1	D10-45	25	175	175	2	18	7000	wheat, 75 cm high, pre-flowering stage
2	D10-45	45	175	175	2	35	7000	wheat, 75 cm high, pre-flowering stage
3	80065	40	410	25	0.5	70	7000	wheat, 75 cm high, pre-flowering stage
4	Micron Air R	4	315	160	3	13.5	1500	wheat, 80 cm high, pre-flowering stage

Table 3. Summary of Meteorological Observation

Test No.	Date	Time	Application	Air Temp. (°C)	Relative Humidity (%)	Wind Speed (km/hr)	Wind Direction	Sky Conditions
1	July 14 1985	6:00 to 6:45 p.m.	Aerial Conv. Nozzle Low Vol.	22	55	(at 2 m) 3-6	WSW	mostly clear
2	July 14 1985	7:00 to 7:30 p.m.	Aerial Conv. Nozzle High Vol.	21	60	2-5	WSW	mostly clear
3	July 15 1985	11:00 a.m. to 12:30 p.m.	Ground Conv. Nozzle Very high vol.	18	30	10	NW	sunny clear
4	July 24 1985	4:00 to 4:30 p.m.	Aerial Rotary Atomizer Low Vol.	27	35	8-13	NW	scattered cloud

Table 4. Deposit Data for Natural and Artificial Wheat Head Samples (in µg insecticide/head)

Trial No. and Type:	#1 Aircraft, Low Volume	#2 Aircraft, High Volume	#3 Groundrig	#4 Aircraft, Rotary Atomizers
1 Natural Heads	7.1 ± 6.2(21)*	12.3 ± 8.6(28)	16.2 ± 11.9(20)	-
2 Artificial Heads	20.6 ± 16.4(48)	52.1 ± 30.9(43)	-	(35)**
3 Glume deposit	4.4 ± 3.4(7)	5.2 ± 4.2(10)	-	-
Stripped Head deposit	3.0 ± 3.1(7)	6.2 ± 3.1(10)	-	-
Total	7.4	11.4		
4 Natural Heads, collected 20 hours after spray	5.5 ± 5.5(18)	9.2 ± 8.8(22)	-	-

* ± standard deviation (in µg/head), together with number of samples averaged (in parentheses).

** from jumpcards, exposed as rolled cylinders, to simulate wheat heads.

Table 5. Deposition Densities, Recoveries and Droplet Size Spectra for the Four Trials

Trial No. and Type:		#1 Aircraft, Low Volume	#2 Aircraft, High Volume	#3 Groundrig	#4 Aircraft, Rotary Atomizers
1	Nominal application rate of insecticide	45 mg/m^2	45 mg/m^2	45 mg/m^2	-*
2	Deposit density, canopy top	44 ± 23 mg/m^2	60 ± 31 mg/m^2	(25) mg/m^2	(7) mg/m^2**
3	Recovery, actual/nominal	100%	130%	60%	-
4	Deposit density, ground level	27 ± 13 mg/m^2	35 ± 18 mg/m^2	(14) mg/m^2	(2) mg/m^2
5	Crop collection density	17 mg/m^2	25 mg/m^2	(11) mg/m^2	(5) mg/m^2
6	Fraction depositing on crop	39%	42%	44%	70%
7	Collection on natural Wheat Heads	1.4 mg/m^2	2.5 mg/m^2	3 mg/m^2	5 mg/m^2
8	Volume median diameter	-	360μ	240μ	135μ, 155μ***
9	σ_g	-	1.2	1.4	1.4

* While dyed water was used as the spray solution in this trial (and hence the nominal application rate of insecticide would be zero), the density data in this column are expressed, solely for comparison purposes with other trials, as if the solution contained 3.3% chlorpyrifos so as to give the same nominal application rate.

** Density figures in parentheses are based on jumpcard analysis, are less reliable, and tend to underestimate.

*** The former figure is from the horizontally exposed jumpcards, the latter from the rolled cylinders. They tended to undercatch the smaller droplets.

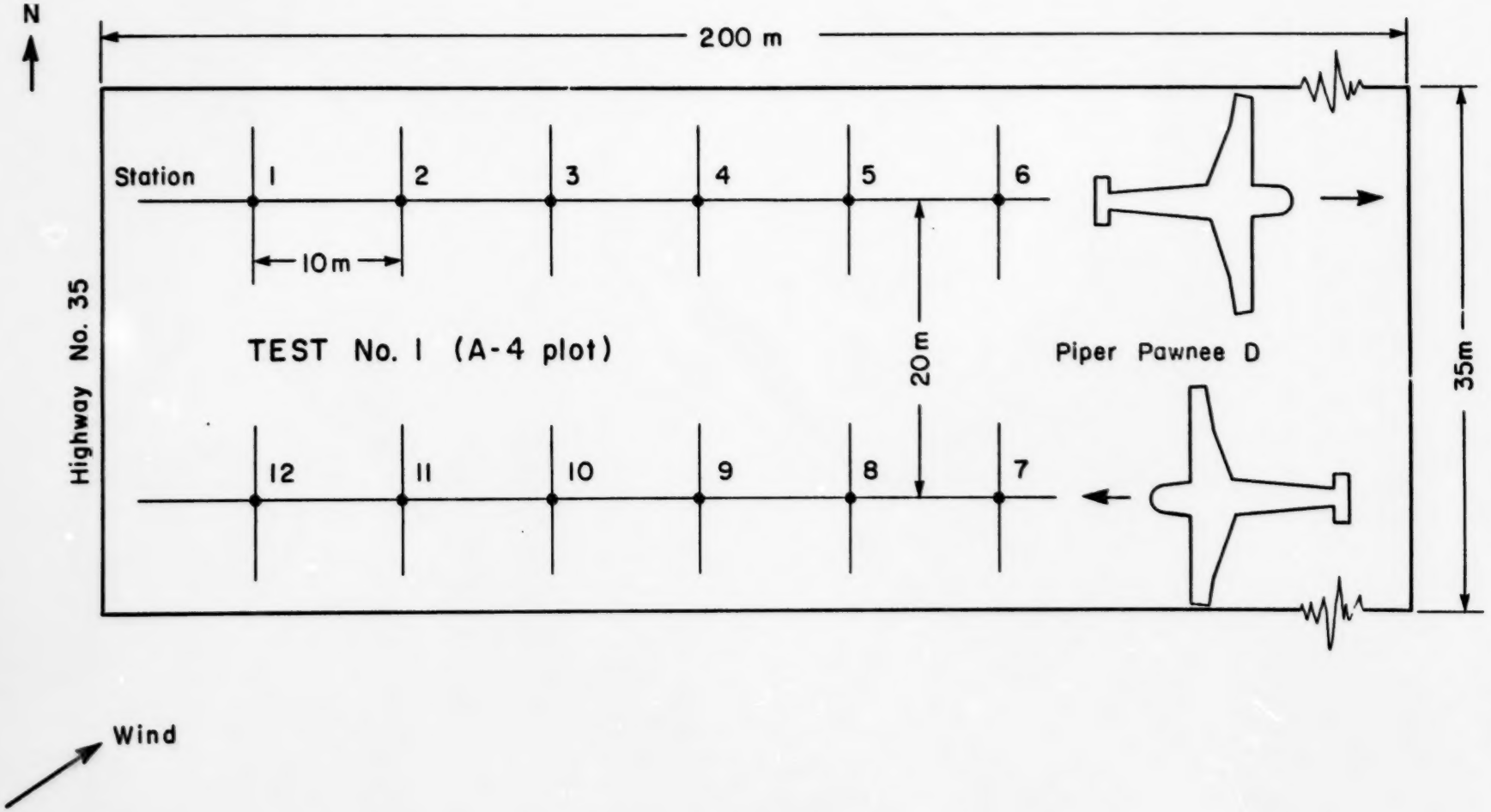

Figure 1. Field Sampling Layout for Low Volume Aerial Spray (Plot A4).

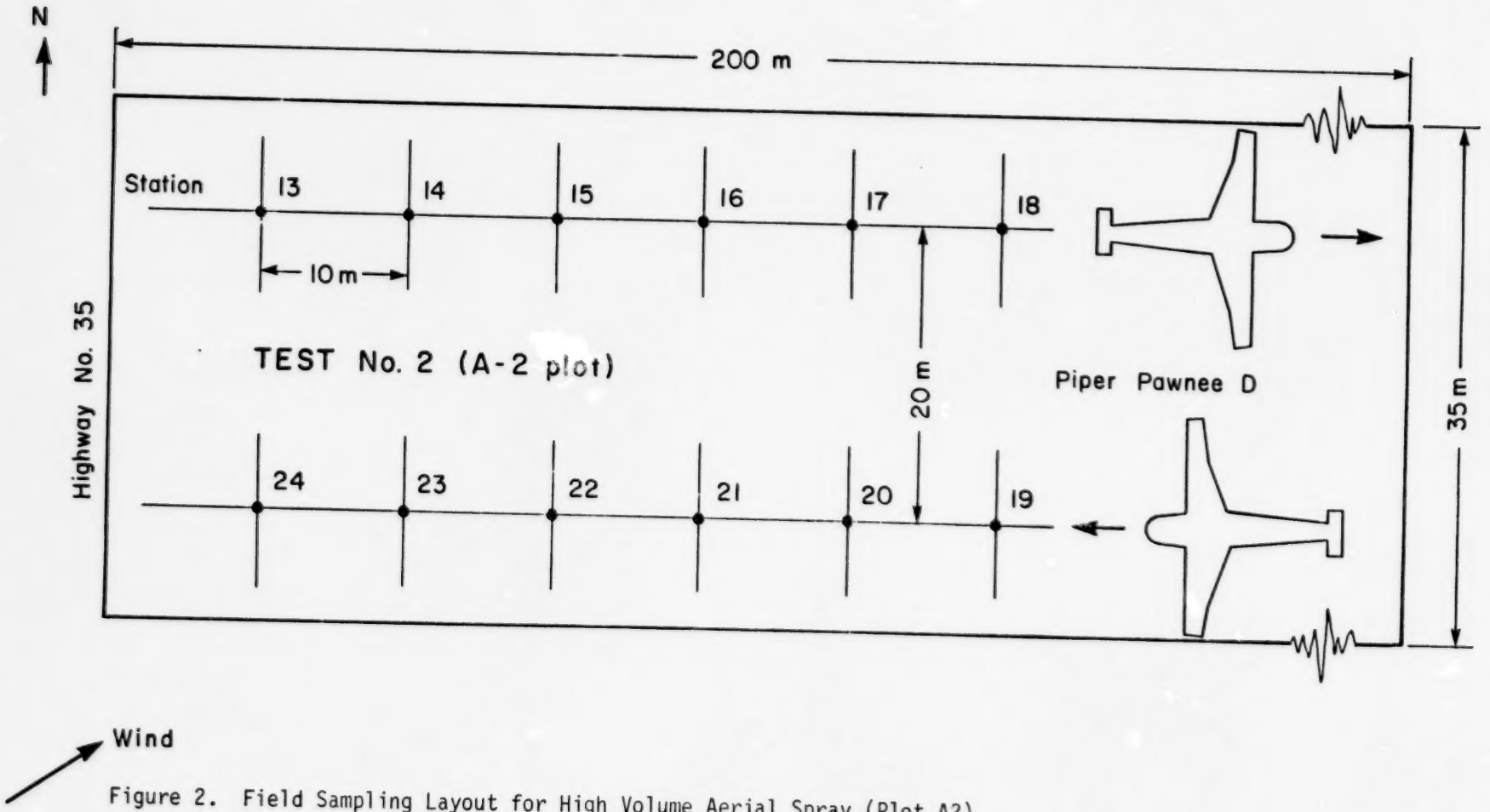

Figure 2. Field Sampling Layout for High Volume Aerial Spray (Plot A2).

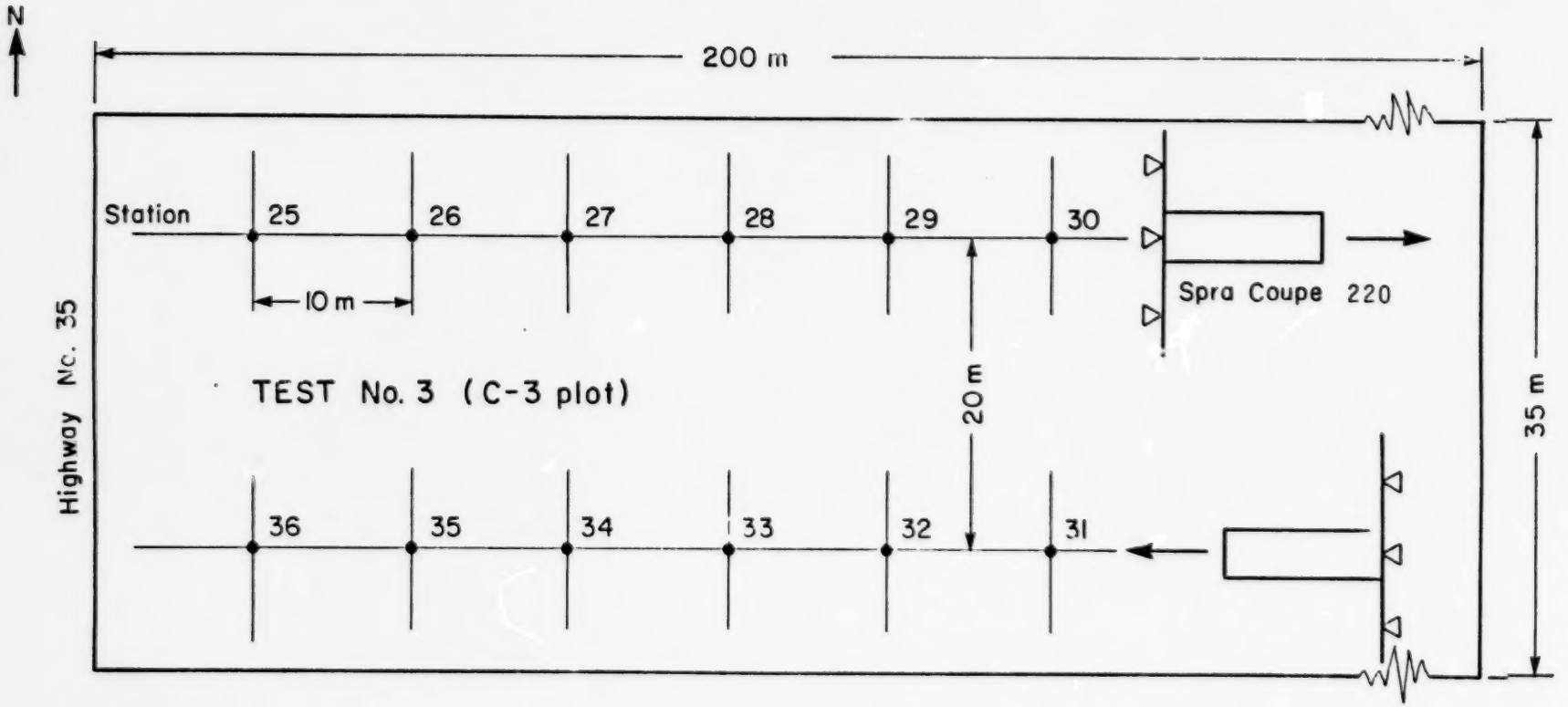

Figure 3. Field Sampling Layout for Ground Spray (Plot C3)

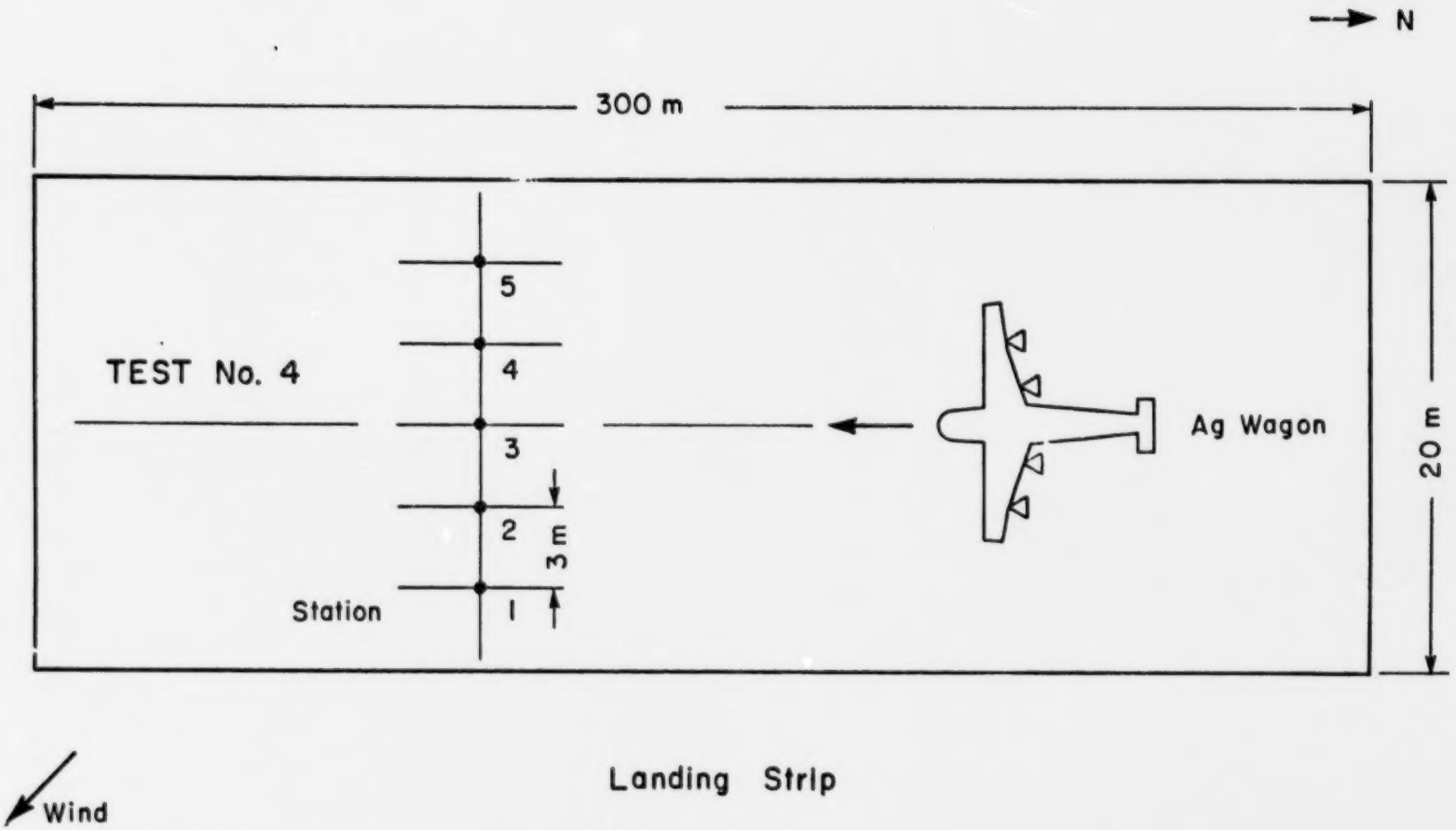

Figure 4. Field Sampling Layout for Rotary Atomizer (Canora)